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A method production of cam shafts  
and to a cam shaft produced by the method.

The invention relates to a method for the production of cam shafts and to a cam shaft produced by way of said method. It is preferably a question of cam shafts for engines for motor vehicles, although the method is also suitable for the production of similar products such as shafts having cams on them for other applications than engines. Such cams would then be elements for converting rotary movement into a linear one, the linearly moving elements running on cams having different curvatures and able to moved against the direction of rotation.

Cam shafts are known which are produced integrally, that is to say forged or cast. Following a mechanical machining operation, the running faces of the cams, which are subject to wear, are hardened by laser rays, electron beams or WiG remelted or, for example, hardened inductively or in a thermal/chemical process. After there is further machining, for example grinding the bearings and the shape of the cams. These cam shafts suffer from the disadvantage that their weight and accordingly the mass to be moved is extremely high. The great mass of the cam shaft has a disadvantageous effect on fuel consumption. A further disadvantage is the intensive machining for processing the blank.

It is furthermore known to produce cam shafts from a plurality of parts. The individual cams are placed on the shaft and preferably secured thereto by welding, swaging or shrinking. In this respect it is possible to overcome the disadvantage of the substantial weight of solid, integral cams, for the shaft can be a hollow shaft, but production is extremely complex.

In accordance with a further known method the individual cams are secured to hollow shaft by causing expansion of the hollow shaft, with the individual cams slipped onto it, by the action of pressure. As a pressure medium use is preferably made of a liquids. The pressure is supplied by way of a piston or stamp (see German patent publications 3,409,541 and 3,521,206). This method does however suffer from the disadvantage that the production of the individual parts, and more particularly fitting together, is technologically extremely complex and the internal shape of the cams is limited.

It is furthermore known to produce cam shafts by producing an elongated hollow body, that is to say a hollow shaft, by internal pressure forming method (IHU method) so that the material is thrust outward as cams individually, in sequence or simultaneously.

Suitable two-part or four-part tools are employed to feed the hollow shaft in the axial direction to ensure that the cams are produced at predetermined positions and forming in an integral manner takes place (WO 97/46341).

The cam shaft produced by this method does however suffer from the disadvantage that although the costs of manufacture are less than with forged cam shafts or those produced from a plurality of parts, the resistance to wear of the cam faces is unsatisfactory. It is impossible to employ the IHU-method on a sufficiently wear resistant material. It is not possible to produce an even running face on the cams in the case of a small spacing between the cams, as is normally the case with motor vehicle cams, for at the points of maximum forming the material is necessarily weakened, and thus strength is unfavorably affected.

If a material is employed for the hollow shaft, which contributes to reducing such shortcomings, it will admittedly allow adequate forming, but the hardness or, respectively, wear resistance can not be achieved, even with a subsequent hardening step. It is however the hardness and wear resistance of the cams which is a basic requirement for a long working life of a cam shaft in a motor vehicle engine. It is also extremely hard, or even impossible, to achieve the necessary material thickness everywhere in the cam shaft, that is to say the shaft itself and more particularly the flanks and tips of the cams.

It is furthermore known to produce the tube sections constituting the cam face with an eccentric profile and to reinforce it by producing a press fit connection. The production of the cam takes place using explosion forming. The individual cams are secured to the cam shaft with a suitable offset in relation to one another (East German patent publication 234,223). Cam shafts currently produced by the method entail complex manufacture and are heavy. The timing of the plastic forming process is not able to be controlled.

One object of the invention is to provide a method for the production of cam shafts, with which by using the known high internal pressure forming method cam shafts may be produced, which have adequate strength, have low flexure, possess a high resistance to torsion and possess high flexural strength in the loaded faces of on the cam flank and tips or crests. The method of manufacture is to be simple. The application of an additional layer, that is to say an anti-wear layer in a further process step, and furthermore complex later machining is not to be necessary. The amount of material used is to be low. The number of the necessary separate parts for the entire cam shaft is to be reduced in comparison known methods of manufacturing cam shafts.

In accordance with the invention this object is to be attained with the features of claim 1 and 8. Advantageous further features are described in claims 2 through 7 and furthermore claims 9 through 17.

The essence of the invention is that suitably hard and wear-resistance bearer rings with thin walls and having the eventual form of the cam are produced, such bearer rings are inserted in an IHU tool by high internal pressure forming (referred to as IHU) and using the axial forces applied to the tube in combination with internal forces applied by way of a pressure medium a single or double stage forming of the tube takes place to yield the cam shaft.

At the end of the forming process the frictional and interlocking connection of the cam with the bearer ring takes place. At the ends of the cam shaft known bearing elements or journals are arranged and then secured in a known fashion.

In accordance with a further preferred development of the invention in a method step, which precedes the above mentioned method, a tube of a material satisfying the necessary requirements for forming and as regards mechanical properties, is so deformed by the known method of kneading, also known as roll kneading, or swaging, that the tube, completely or partially, or only the cam shaft ends, is plastically formed, that is to say for instance stretched and/or made thicker. At the ends shaped elements for drive and control elements, for instance the seat for gear wheels are produced. In the following the above mentioned method step the IHU method is used to flare out the tube that region, in which the cams are arranged, the IHU tool having been previously had the bearer rings inserted into it in accordance with the positions of the cams.

In the case of cams which have a very sharp curvature there is the disadvantage, when the bearer rings have a constant wall thickness, that the tube is subject to a high degree of deformation and in some cases a multi-stage forming method will be necessary. This leads to an increase in manufacturing costs and a reduction in productivity. Furthermore in the cylinder head there are interfering structures clear of the cam shaft and between or alongside the cams. They mean that the space available is reduced and the IHU process is harder to perform. This limitation is only, if at all to be overcome by the use of a complicated, multi-stage IHU process. This in turn leads to high costs of production. Therefore an advantageous form of the method and, respectively, of the shaft produced in it, is such that the bearer rings, which are produced in a separate method, externally possess the functionally dependent outline and internally have and somewhat greater diameter than the tube. The wall thickness of the bearer ring is not constant and is greater at the cam tip or crest. This means that the bearer ring has, as a cam, a variable thickness and its inner periphery is not a circle.

The method in accordance with the invention is essentially that two or more modern manufacturing methods are combined with each other.

It is an advantage to produce at least one groove radially in the bearer ring in order to prevent displacement of the bearer ring because during the action of pressure such groove becomes filled with material of the shaft.

Another preferred feature of the invention is such that the drive and/or control elements are also secured on the shaft using the IHU method. Furthermore bearing faces may be produced by expansion of the tube using the IHU method as well. The cold solidification or hardening of the tube material owing to the plastic displacement process is particularly advantageous.

The cam shaft produced in accordance with method of the invention is extremely light in weight owing to the hollow cams and very thin walled bearer rings and has a high degree of stiffness. The advantage that the bearer rings at the most only have to be machined to a minor extent. Their hardness meeting requirements is already provided, this meaning that later hardening, which is normally necessary, for example inductive hardening or remelting hardening in a vacuum process, can be dispensed with.

Further development of the method leads to the additional advantage that the round kneading or upsetting in combination with the IHU method - unlike the case with all other manufacturing methods - only involves very low manufacturing complexity and consequently low costs. The costs are more especially reduced because the number of individual parts to be separately manufactured and then to be fitted is extremely low. Owing to manufacture in accordance with the invention sources of error are minimized, which so far occurred in the fitting together of parts so far practiced. A substantial advantage of the method is due to the fact that the kneading method renders possible the production of functional elements, which as regards their geometry, dimensional accuracy and surface quality require very little additional machining. Frequently only a grinding process is necessary to finish them.

The cam shaft produced in the method of the invention has a small number of separate parts. At the end of the forming process the cam rings are connected with the shaft frictionally and in an interlocking manner.

It is advantageous as well to provide the bearer ring on the side facing the tube on one or both sides with a chamfer. This furthermore prevent lateral displacement on the shaft.

An advantageous design of the bearer rings is such that the bearer ring, as in the prior art, consists of plastics or sintered materials. Such materials offer the advantage of simple manufacture with low manufacturing costs.

Furthermore ceramic materials may be utilized. They bring the advantage of maximum wear resistance and minimum weight so that very light cam shafts may be produced.

The invention will now be described with reference to two working examples illustrated in the accompanying drawings.

Figure 1 shows a longitudinal section taken through a finished cam shaft.

Figure 2 shows a cross section taken through a cam on the shaft.

Figure 3 shows part in longitudinal section taken through a cam on the shaft.

Figure 4 shows a cam shaft formed by round kneading/upsetting.

Figure 5 shows a cam shaft with bearer rings of non-constant thickness in section.

Figures 1 through 3 show the manufacture of a cam shaft in the IHU method.

By IHU forming in a pressing mold a cam shaft is produced from a thin walled tube 1 of readily deformable material so as to comply with contours, that is to say the positions where a cam is to be seated are deformed outward in accordance with the dimensions of the cam 2 and its position. The shaft with its cam 2 is a single hollow body. In a known process bearer rings 3, as shown in figures 2 and 3, are manufactured. For this purpose a tube of wear-resistant material is so shaped that the eventual form of the bearer ring 3 (cam) is set and the ring is hardened. The prefabricated tube 1, which is to be formed to constitute the cam shaft, is thrust through the bearer rings 3 and together with them placed in the opened forming tool. All individual parts are therefore locked in position. The forming tool is closed axial and the force for forming may be applied. The application of force starts with a predetermined axial force on the tube 1 and/or the tool, supported by a predetermined internal pressure in the tube 1. After completely closing the tool further operations are performed with an orthodox IHU process to connect the tube 1 and the bearer ring 3 by friction and by an interlock. Bearing or drive elements 5 are arranged in a known manner on the end of the tube 1. It is also possible to secure same to the tube 1 using the IHU method as well.

It is furthermore possible to provide a groove 4 in the interior of the bearer ring 3 so that the hold of the cam 2 is improved since the groove becomes filled with the material of the tube 1. It is also possible to provide the bearer ring with chamfers which are filled with material during following IHU method.

The manufacture of a cam shaft by the IHU method in combination with the kneading method will now be described in a further example on the basis of figure 4.

The tube 1 of a readily deformed material is deformed at its ends by round kneading or upsetting to increase its thickness. On one side its internal diameter  $D_i$  is thus reduced and its external diameter  $D_A$  is defined so that a zone 6 reinforcing the cam shaft is produced. At the outer end a functional element 7 is produced, whose seat is sized by grinding. At the other end again by kneading or upsetting the internal diameter  $D_i$  of the end already described is reduced simultaneously and a further functional element 7 (bearing seat, cam etc.) is created. In the following method step a collar 8 is produced by upsetting as well which is required for the flank mounting of other components.

After the first method stage the bearer rings 3, produced in a separate process, which correspond to the shape of the cams and the sprocket (not illustrated) are mounted by the IHU method frictionally and with an interlocking effect. For this purpose the bearer rings 3 and the sprocket are placed in the IHU tool.

Figure 5 shows a design of the cam shaft in which the bearer ring 3 has a varying thickness.

The tube 1 of a readily deformable material has an external diameter  $d_a$ . The bearer ring 3 of sintered metal has an outer form as dictated by function and internally is not circular. Its internal diameter  $D_i$  is somewhat larger than the external diameter  $d_a$  of the tube 1. The thickness of the bearer ring 3 is not constant. The height A, which would result if one were to assume a constant thickness of the bearer ring, is larger than the height A' of the maximum displacement of the tube 1 and thus the radius  $R_i$  at the deformation of the tube 3 is larger than  $R_i$  assuming an equal thickness  $c$  of the bearer ring 3. In this part the thickness  $c$  of the bearer ring 3 is larger and extends into the part with a constant thickness  $c$ .

Even although in this form the bearer ring 3 is slightly more expensive, the reduced costs of the IHU method are significant on balance, such method being possible in one step.